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Biodiesel production: a preliminary study from Jatropha Curcas

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ABSTRACT
The world is getting modernized and industrialized day by day. As a result vehicles and engines are increasing. But energy sources used in these engines are limited and decreasing gradually. This situation leads to seek an alternative fuel for diesel engine. Biodiesel is an alternative fuel for diesel engine. In this study, crude Jatropha curcas oil was used as feedstock for biodiesel production by alkali-catalyzed methanolysis. The utilization of liquid fuels such as biodiesel produced from Jatropha oil by transesterification process represents one of the most promising options for the use of conventional fossil fuels. This paper investigates the prospect of making of biodiesel from jatropha oil. Jatropha curcas is a renewable non-edible plant. Jatropha is a wildly growing hardy plant in arid and semi-arid regions of the country on degraded soils having low fertility and moisture. The seeds of Jatropha contain 50-60% oil. Biodiesel, a promising substitute as an alternative fuel has gained significant attention due to the predicted shortness of conventional fuels and environmental concern. In this study the oil has been converted to biodiesel by the well-known transesterification process and used it to diesel engine for performance evaluation.

1. INTRODUCTION

In today's world, petroleum is clearly the most important energy source, providing more than half the world's power, as well as being a basic material used in the manufacture of fertilizers, synthetic fibers, plastics, and synthetic rubber (Meher LC et al. 2006 & Speight JG, 2007). Demand is ever-increasing worldwide, yet petroleum resources are finite (Meher LC et al 2006) and non-renewable (Meher LC et al 2006). Concerns about dwindling supplies, its unstable and rising cost, and environmental problems have motivated researchers more extensively to seek alternative, renewable energy sources. Among these alternative sources, vegetable oils have gained considerable attention since they are derived from renewable resources, can be domestically produced, and are not as harmful as petroleum to the environment (Demirbas A, 2009).

Transesterification is a very slow reaction which can be accelerated by the presence of a catalyst, such as a strong acid or base (MaF, Hanna MA in 1999). Base catalysis is much faster and has lower corrosion than acid catalysis (Canakci M et al. 1999 & De Oliveira JS et al. 2009), and so, is most used commercially. Suitable alcohols used in this reaction include methanol, ethanol, propanol, butanol, and amyl alcohol. The most common is methanol, due to its low cost and its physical and chemical advantages. Alkaline catalysts used for transester-ification include sodium and potassium hydroxides, carbonates, and alkoxides. The usual alkalis are sodium and potassium hydroxides.

The plant that is generally cultivated for the purpose of extracting jatropha oil is Jatropha curcas. The seeds are the primary source from which the oil is extracted. Owing to the toxicity of jatropha seeds, they are not used by humans. The major goal of jatropha cultivation, therefore, is performed for the sake of extracting jatropha oil. Analysis of jatropha curcus seed shows the following

1.1. Chemical compositions

Moisture: 6.20%
Protein: 18.00%
Fat: 38.00%
Carbohydrates: 17.00%
Fiber: 15.50%
Ash: 5.30%

The oil content is 25-30% in the seed. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids. These are some of the chemical elements in the seed, cursin, which is poisonous and render the oil not appropriate for human consumption. Oil has very high saponification value and being extensively used for making soap in some countries. Also oil is used as an illuminant in lamps as it burns without emitting smoke. It is also used as fuel in place of, or along with kerosene stoves. Jatropha curcus oil cake is rich in Nitrogen; Jatropha curcus oil cake is rich in Nitrogen, Phosphorous and Potassium and can be used as organic manure. By thermodynamic conversion process, pyrolysis, useful products can be obtained from the jatropha oil cake. The liquid, solid (char), and gaseous products can be obtained. The liquid can be used as fuel in furnace and boiler. It can be upgraded to higher grade fuel by transesterification process.

The seeds of jatropha contain (50% by weight) viscous oil which can be used for manufacture of candles and soap, in the cosmetic industry, for cooking and lighting by itself or as a Diesel /paraffin substitute or extender. The latter use has important implications for meeting the demand for rural energy services and also exploring practical substitute for fossil fuels to counter green house gas accumulation in the atmosphere.

There are number of variety of jatropha. Best among these are jatropha curcus. Jatropha oil is an important product from the plant for meeting the cooking and lighting needs of the rural population, boiler fuel for industrial purpose or as a viable substitute for Diesel. About one- third of the energy in the fruit of jatropha can be extracted as oil that has a similar energy value to Diesel fuel. Jatropha oil can be used directly in Diesel engines added to Diesel fuel as an extender or transesterified to a bio-diesel fuel. There are some technical problems to using jatropha oil directly in Diesel engines that have yet to be completely overcome.

Moreover, the cost of producing jatropha oil as a Diesel substitute is currently higher than the cost of Diesel itself. Oil presses have been used for the purpose of oil extraction as simple mechanical devices - either powered or manually driven. Among the different oil presses that are used for jatropha oil extraction, the most commonly used presses include the Bielenberg ram press.

The purpose of this research work is to investigate the fuel properties of Jatropha oil and production of bio-diesel from Jatropha oil. Investigate the fuel properties of bio-diesel and performance test diesel engine by using bio-diesel.

2. EXPERIMENTAL

2.1. Materials

All chemicals used in the experiments, such as methanol, sodium hydroxide, and n-heptane, were of analytical reagent (AR) grade. The methyl esters, such as methyl heptadecanoate, methyl esters of palmitic, palmitoleic, stearic, oleic, and linoleic acids, were of GC reference standards.

2.2. Extraction of oil

The Jatropha curcas seed is small, black in color, and ellipsoid, with an average size of about 1.7-1.9 cm long and 0.8-0.9 cm thick. The weight of 100 seeds is about 69.8 g. The Jatropha curcas oil was mechanically extracted from the seeds using a screw press, and then allowed to settle until the impurities precipitated. The extracted oil was filtered with suction by using nylon mesh filter cloth with mesh opening of 5 microns. 100 kg of Jatropha curcas seeds provided on average of 25 L of extracted oil which was clear, viscous, and yellowish in color.

2.3. Equipment

The reactions were carried out in a 250 mL three-necked flat-bottom flask equipped with a reflux condenser (to reduce the loss of methanol by evaporation), thermometer, and a stopper to add the catalyst solution. The reaction mixture, 100 mL in volume, was heated and stirred by a hot plate with a magnetic stirrer.

2.4. Experimental conditions

The alkali-catalyzed methanolysis of the crude Jatropha curcas oil was carried out by using sodium hydroxide as catalyst at atmospheric pressure. The reaction mixture was well-stirred at a constant stirring speed of 600 rpm for all test runs. The experiments were planed to investigate the optimum conditions and to study the effects of the variables on the reactions, such as methanol-to-oil molar ratio, catalyst concentration, reaction temperature, and reaction time. In the present study, the reaction was conducted at different methanol-to-oil molar ratios (4:1, 6:1, 8:1, and 10:1), catalyst concentrations (0.25, 0.5, 1.0, 1.5, and 2.0% w/w of oil), reaction temperatures (32, 40, 50, and 60ºC), and reaction times (5, 10, 20, 30, and 40 minutes).

2.5. Biodiesel production

In this study, the base catalyzed transesterification is selected as the process to make biodiesel from Jatropha oil. Transesterification-ion reaction is carried out in a batch reactor. For transesterification process 500 ml of Jatropha oil is heated up to 70^{0}C in a round bottom flask to drive off moisture and stirred vigorously. Methanol of 99.5 % purity having density0.791 g/cm^3 is used. 2.5 gram of catalyst NaOH is dissolved in Methanol in bi molar ratio, in a separate vessel and was poured into round bottom flask while stirring the mixture continuously. The mixture was maintained at atmospheric pressure and 60°C for 60 minutes. After completion of transesterification process, the mixture is allowed to settle under gravity for 24 hours in a separating funnel. The products formed during transesterification were Jatropha oil methyl ester and Glycerin. The bottom layer consists of Glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil. The upper layer consists of biodiesel, alcohol and some soap. The evaporation of water and alcohol gives 80-88 %pure glycerin, which can be sold as crude glycerin is distilled by simple distillation. Jatropha methyl ester (biodiesel) is mixed, washed with hot distilled water to remove the unreacted alcohol; oil and catalyst and allowed to settle under gravity for 25 hours. The separated biodiesel is taken for characterization.

2.6. Economic of Jatropha cultivation

After completion of transesterification process, the mixture is allowed to settle under gravity for 24 hours in a separating funnel. The products formed during transesterification were Jatropha oil methyl ester and Glycerin. The bottom layer consists of Glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil. The upper layer consists of biodiesel, alcohol and some soap. The evaporation of water and alcohol gives 80-88 %pure glycerin, which can be sold as crude glycerin is distilled by simple distillation.

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3. RESULTS AND DISCUSSION

Characterization of crude Jatropha curcas oil Crude Jatropha curcas oil was used without having undergone any further refining for use as a biodiesel feedstock. Its properties were established to ascertain suitability for biodiesel production and to determine a suitable production process for this feedstock. Characteristics, determined by standard methods, of the fatty acid composition, density, viscosity, FFA and water contents in the oil are shown in here.

Properties of crude *Jatropha curcas* oil. Property	**Crude *Jatropha curcas* oil**
Fatty acid composition	969.33
(i) Palmitic acid	13.77
(ii) Stearic acid	6.77
(iii) Oleic acid	41.68
(iv) Linoleic acid	35.55
Density at 15°C, kg/m3	918.6
Free fatty acid content % w/w	0.52
Water content, % w/w	0.1250

The fatty acid composition of oils is an important factor which affects the performance of biodiesel in an engine; saturated methyl esters have higher cetane values and oxidation stability, but poorer low-temperature flow properties than those of unsaturated ones (Ramadhas AS et al. 2005 & Park JY, Kim DK et al. 2008). The subject, crude Jatropha curcas oil, consisted of a high proportion of unsaturation, comprised predominantly of oleic and linoleic acids and a lower proportion of saturation, comprised primarily of palmitic acid. In this study, the average molecular weight of the oil was calculated to be 866.13 g.

The crude Jatropha curcas oil was approximately 11 times more viscous than diesel fuel, and reduced to a level close to that of diesel after conversion to biodiesel. In this study, the FFA and water contents measured were 0.52% w/w and 0.1250% w/w respectively, thus demonstrating the feasibility of alkali-catalyzed methanolysis of crude Jatropha curcas oil.

4. CONCLUSION

This study demonstrates that biodiesel can be produced successfully from crude Jatropha curcas oil by alkali-catalyzed methanolysis. The optimum conditions were a methanol-to-oil molar ratio of 6:1, a catalyst concentration of 1% w/w of oil, and a reaction temperature and reaction time of 60°C and 40 minutes, respectively. Produced under these conditions, the methyl ester content of the Jatropha curcas biodiesel achieved 98.6% w/w, and all of the measured properties of Jatropha curcas biodiesel complied with the limits prescribed by Thai biodiesel (B100) specifications and international standards EN 14214:2008 (E) and ASTM D 6751-07b, with the exception of lower oxidation stability. The results indicate that all of the reaction variables in this study had positive effects on the reaction. However, it was not possible to achieve methyl ester formation by using a catalyst concentration of 2% w/w of oil, due to soap formation. Due to the low price of sodium hydroxide, the short reaction time, and high methyl ester content obtained, these optimum conditions can be used in large-scale production to reduce the cost of production.

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